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INTRODUCTION

Native to Europe and Asia Minor, watercress (*Nasturtium officinale* R. Br.) is a leafy aquatic perennial vegetable crop of economic importance to Hawaii. According to the Hawaii Agricultural Reporting Service (1985), 1,530,000 pounds (695,000 kilograms) of watercress were produced on 35 acres (14 hectares) of land in 1985. The total farm value was $1,212,000. Most of Hawaii's watercress crop is raised on the island of Oahu in the Aiea, Pearl City, and Waipahu districts bordering Pearl Harbor, where the supply of spring and artesian well water is plentiful. Commercial growing of watercress is permitted by the Department of Health only in areas where the water is pure enough for drinking.

GROWING CONDITIONS

There are two major environmental requirements for the production of watercress. The availability of a large quantity of clean, continuously flowing water is of the utmost importance for the commercial growing of this crop. A supply of 1,000,000 gallons per acre (9,400,000 liters per hectare) per day of groundwater (spring or artesian well) will allow optimal growth, provided water temperature and nutrition are adequate. Water temperatures above 78°F (25.5°C) will cause slow or poor growth.

Bright, sunny days with little or no cloud cover throughout the growing cycle of the crop are also critical to good commercial production of watercress. This is especially important because of the leafy growth of this crop. Appropriate amounts of sunlight for watercress cultivation are found on the leeward coasts of all islands in Hawaii.

Watercress is grown in shallow ponds or beds with ¼ to 2 inches (0.6 to 5 cm) of water flowing continuously at a rate of 2 to 4 feet (0.6 to 1.2 m) per second. The water movement throughout the pond must be uniform to obtain uniform growth. The crop will not produce luxuriant growth in areas where the water circulation is poor. The productivity of the watercress bed depends mainly on the continuity, force, and regularity of the water current.

Watercress obtains most of the nutrients necessary for its growth from the water in which it grows. Nitrogen, in nitrate form, is the most important nutrient for commercial watercress production. The nitrate content of the groundwater located in the growing areas in Hawaii ranges from 1 to 4 parts per million (ppm). The best growth of watercress is achieved when the nitrate content is in the upper range.

High chloride content of the water or high pH can also restrict watercress production. In general, water with a chloride content greater than 1000 ppm or pH above 7.5 will not sustain commercial watercress production.

Air temperature also plays an important role in the production of watercress. Optimum daytime air temperatures for watercress growth are 70 to 85°F (21 to 29°C). Consequently, the best growth of watercress occurs during Hawaii's cool winter season (November through April). Use of an intermittent overhead sprinkler system operated throughout the daylight hours moderates the effect of high daytime temperatures by evaporative cooling of the crop. Watercress treated with a sprinkler system is watered for 4 minutes every half hour to achieve the optimum growing temperatures.

STRAIN TO PLANT

There are two species of watercress that are grown commercially worldwide for their stems and leaves, *Nasturtium officinale* and *N. microphyllum*. *N. officinale* is the only one grown in Hawaii, but within this species there are several unnamed cultivars or strains being grown. Most of the selections for Hawaii have been made based on three criteria: (1) the ability to produce well during the cool winter months, when demand for the product is high, (2) a vegetative growth habit during the long days of Hawaii's summer, when watercress normally flowers, and (3) resistance or tolerance to turnip mosaic virus.

The dominant strain of watercress produced commercially in Hawaii is 'Sylvasprings'. Originally developed in Dorset, England, this strain is high yielding. It is dark green, somewhat mild in flavor, and grows very rapidly and densely under favorable conditions. Started from seed in Hawaii, it has much genetic diversity. Early work with this strain showed that some of the seedlings exhibited symptoms of turnip mosaic virus. Susceptible individuals have since been rogued, and the remaining stock is being used as the main crop for the majority of Hawaii's industry. It is a high-yielding winter crop but is sensitive to warm temperatures experienced during the summer. This problem has been overcome by the use of intermittent overhead sprinkling.

BED CONSTRUCTION

The best site for watercress beds or ponds is a flat area with a slope of ½ to 1 percent below the water source. There should be sufficient slope to assure a constant flow of water and to permit complete drainage of the beds. The more water there is, the steeper the grade should be to ensure proper drainage. The grade of the bottom should ensure that the water over the bed can be maintained at a uniform depth, and the bottom must be firm for optimum working conditions. If the bottom is soft, gravel or crushed rock must be added to give it firmness. After completion of the beds, water should be run through them to check for high or low spots. The grade of the bed at right angles to the direction of the water flow should be level to prevent lateral movement of the water.

The size of each bed usually depends on the amount of water available and the slope of the field. Standard beds in Hawaii are 40 feet wide by 80 feet long (12 m x 24 m). Beds are oriented lengthwise in the direction of the water flow. Dikes of hollow concrete tiles 8 inches x 8 inches x 16 inches (20 cm x 20 cm x 40 cm) are constructed around each bed. The tiles function as adjustable passageways for the regulation of water flow between successive beds (Fig. 1) and provide a footpath for access to the beds.

PLANTING

Watercress is easily propagated by seed, stem, or terminal shoot cuttings. Terminal shoot cuttings are preferred by commercial growers in Hawaii because they result in faster growth. With a water depth of approximately ¼ inch (6 mm), bunches of four to six cuttings are placed on the surface of the bed at 1-foot intervals. The cuttings should be 1 foot (30 cm) long, preferably with roots on the basal ends, and are placed lengthwise in the water flow, with the basal end pointing downstream (Fig. 2). It takes 10 to 14 days for a root system suitable for proper anchorage to develop. After this time more water can be directed into the beds as needed.

The crop requires about 45 days from planting to harvest. As the crop grows, the water depth should be increased slowly to 2 inches (5 cm) and then reduced after harvest. Subsequent crops are produced from the stems left in the bed after harvesting as well as an additional planting of vegetative tip cuttings on top of the residue. The addition of cuttings to the crop residue can be made immediately after harvesting. The next crop will again require approximately 45 days from the time of planting until harvest.

There is limited use of commercial fertilizers in the watercress cropping system in Hawaii. Nutrient requirements of the developing crop are met primarily by increasing the water supplied to each bed throughout the crop cycle. As a greater volume of water is supplied to the crop, a greater amount of nutrients becomes available. The major nutrient necessary for obtaining luxuriant watercress growth is nitrogen. A prospective watercress farmer should have the water tested for adequate nitrogen levels as well as for proper pH and chloride content before planting. Application of fertilizers to the water and beds of watercress farms has not been cost effective. In fields where there is inadequate spring or well water flow to provide for the needs of the crop, recirculated water can be used (Fig. 3). Recirculated water is successful only when the water is pumped continuously to the beds where it is needed.

Foliar application of chelated iron sulfate has been quite successful in remedying chlorosis due to iron deficiency. Use of a chelated iron formulation of 8 percent iron at a rate of 1 quart per acre is recommended for most situations in which iron deficiency is a problem.

PESTS

The major insect pest affecting watercress in Hawaii is the diamondback moth (*Plutella xylostella*), whose larvae cause extensive chewing damage on the watercress leaves and shoots (Fig. 4). This insect cannot be controlled by chemical insecticides. The most effective method now being used by farmers is an intermittent overhead sprinkler system (Fig. 5). Operated during daylight hours to achieve cooling of the crop, the sprinkling is continued into the night, often as late as midnight, to disrupt mating, breeding, and egg laying by the adult moths. The efficacy of this system is improved by the presence of several biological control agents that occur in the watercress fields. The most important of these are the parasitic wasp *Cotesia plutella*, which lays its eggs in the diamondback moth larvae, and the granulosis virus, which, though slow acting, causes the death of infected larvae.

Other minor insect pests that can cause damage are cyclamen mites (*Steneotarsonemus pallidus*), cotton aphids (*Aphis gossypii*), green peach aphids (*Myzus persicae*), turnip aphids (*Hyadaphis erysimi*), grass sharpshooters (*Draeculacephala minerva*), and southern green stink bugs (*Nezara viridula*). Cyclamen mites attack the growing points of the crop, causing distortion of young leaves and stunting growth. The mites are easily controlled by using an intermittent overhead sprinkler system.

All of the aphid species cause similar damage. The shoots, when infested, are curled and stunted. Heavy infestation of aphids can

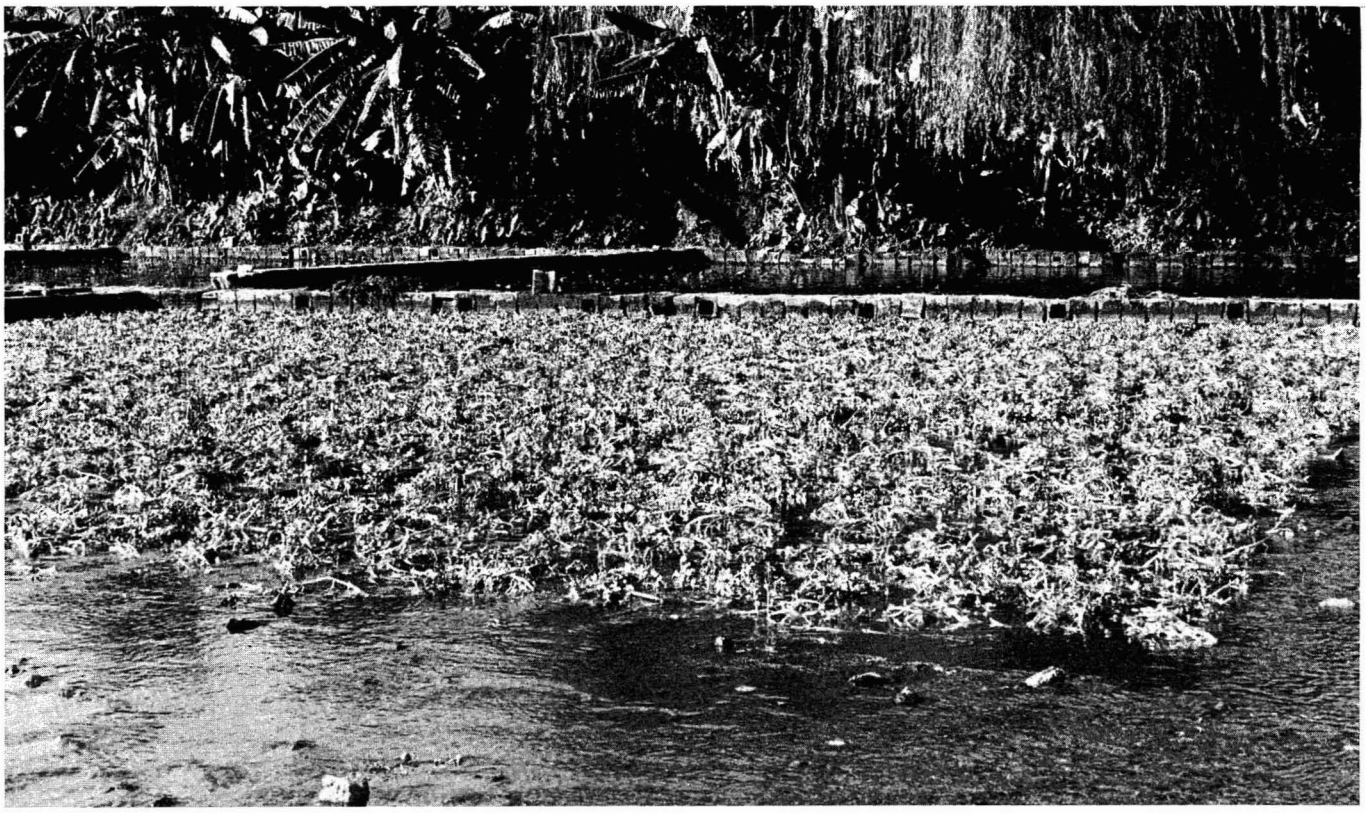

Figure 1. Newly graded and planted watercress with tile borders.

Figure 2. Proper placement of watercress cuttings.

Figure 3. Recirculation of water to augment inadequate spring or well water flow.

Figure 4. Watercress damage caused by the feeding of diamondback moth larvae.

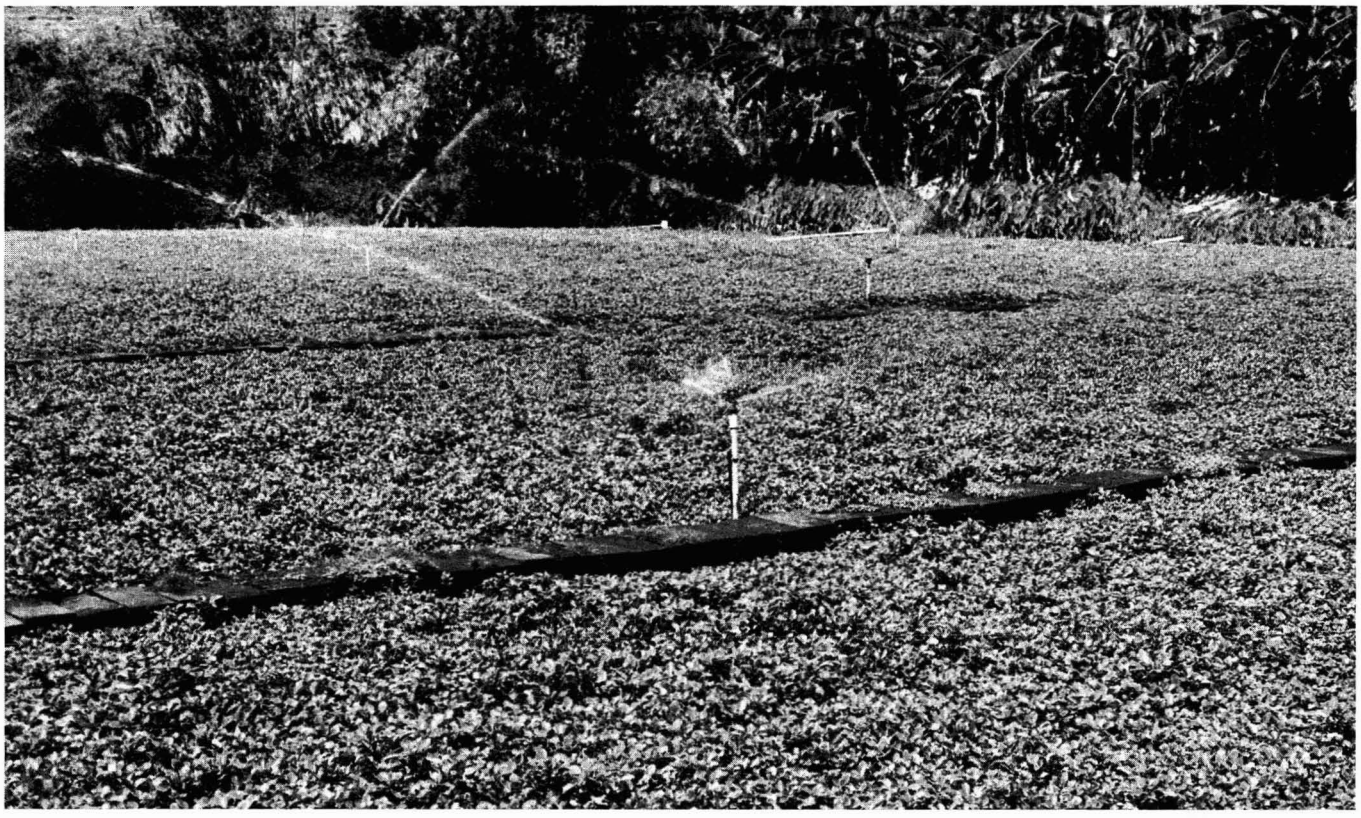

Figure 5. Intermittent overhead sprinkler irrigation provides cooling as well as diamondback moth control.

Figure 6. Algal growth in watercress bed.

Figure 7. Harvesting watercress.

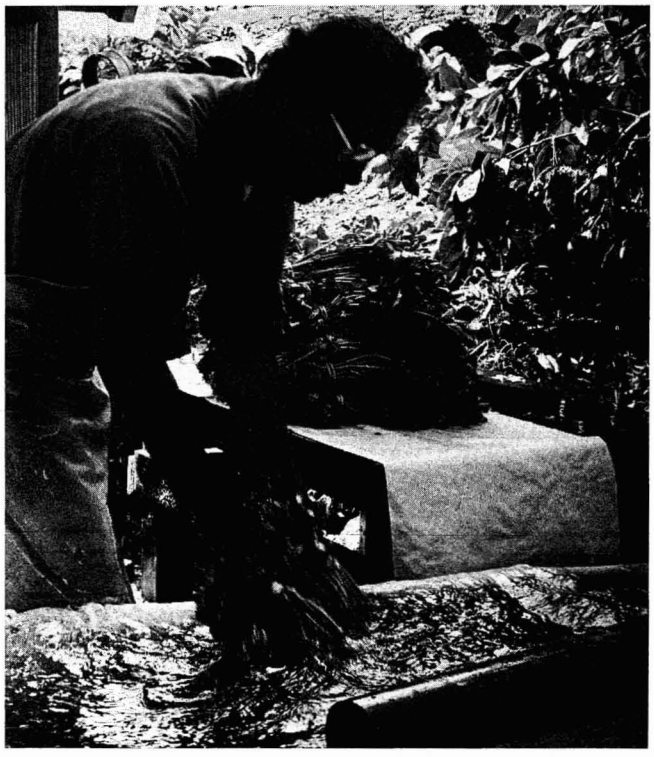

Figure 8. Washing and bundling watercress.

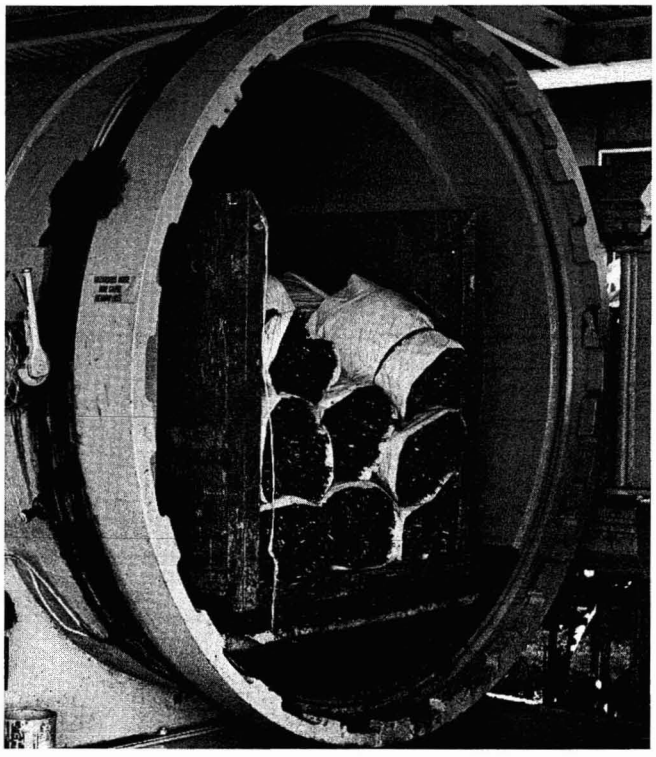

Figure 9. Bundled watercress in vacuum cooler.

also produce an unsightly finished product. The grass sharpshooter injects a mildly phytotoxic saliva into the leaves when feeding, causing a mottled leaf surface. Southern green stink bug damage is caused by the insertion of the insect's stylus into the main stem of the plant, causing the shoot above the feeding site to wilt and die. Chemical control of these pests is achieved by timely applications of insecticides currently registered for use on watercress. These control measures are outlined in Table 1. Care should be taken when using these chemicals, as they can also destroy the wasp parasite of the diamond-back moth and some predators of the aphid species.

Table 1. Chemical control of aphids, grass sharpshooters, and southern green stink bugs on watercress

Chemical control	Application rate*	Harvest restriction
Methomyl 25% L (Lannate, Nudrin)	1 pint/acre	7 days
Diazinon AG500	1 pint/acre	5 days
Cythion WSFI 8E	2 pints/acre	7 days

*Follow all label directions carefully.

Cercospora leaf spot, caused by a fungal organism, can be troublesome during warm, humid weather. A fungal spray of tri-basic copper sulfate, which may be helpful in controlling the disease, is not now being used by commercial growers because the disease has only a marginal effect on crop yield.

The aquatic greater duck weed, *Lemna polyrrhiza*, and the water fern, *Azolla* spp., occasionally cause problems in the ponds. These floating weeds multiply very rapidly and can choke out the newly planted crop or the young ratoon crop. When the water becomes warm, excessive algae growth commonly develops around the root system of the watercress (Fig. 6). This in turn causes the water flow through the watercress beds to become uneven, leading to poor growth. The duck weed, water fern, and algae can be controlled by the tedious process of using a net to scoop them out of the ponds.

HARVESTING

Watercress is harvested when the plants reach a height of 12 to 14 inches (30 to 35 cm) above the water level. The harvesting is done by grasping the stems in a bunch in one hand and cutting them with a sickle in the other (Fig. 7). Each bunch, which is approximately ¾ pound (340 g), is measured by the size of the harvester's grasp. The bunches are cut 12 to 14 inches long (30 to 35 cm), and the yellow or spotted lower leaves are stripped. The bunch is then secured with twist ties.

The harvested bunches are gathered from the beds and transported in wheelbarrows to the packing shed, where they are washed in clean water and bundled, with 30 bunches to a bundle (Fig. 8). After packing, the watercress is vacuum cooled (Fig. 9) and then stored in a large walk-in refrigerator at 34°F (1°C). The vacuum cooling process permits the growers to store the watercress for up to one week in the refrigerator. Because the crop is usually delivered to market the next day, however, the main effect of vacuum cooling is to extend the shelf life. The high water content of watercress (95 percent) makes it a very perishable commodity. Utmost care must be taken in handling from the field to the marketplace to the home to ensure that the consumer receives a quality product.

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